Feature Extraction Techniques and Minutiae-Based Fingerprint Recognition Process

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***Abstract* - In this paper we intend to propose a high-speed method for fingerprint recognition based on minutiae matching, which, unlike conventional minutiae matching algorithms, also takes into account region and line structures that exist between minutiae pairs, allowing getting more structural information of the fingerprint and resulting in stronger and more accurate matching of minutiae.**

***Keywords* - Fingerprint verification, image processing, template matching, and minutiae.**

I. INTRODUCTION

Biometric systems identify a person using behavioral and physiological biometric data. The behavioral biometrics are: signature, gait, speech and keystroke, which change with age and environment. Physiological characteristics don't change throughout the lifetime of a person. Such characteristics include face, fingerprint, palm print and iris. The biometric systems verify and identify a person using his biometric data.

Historically speaking, fingerprints have been long associated with criminology, specifically forensics. Development of cheaper and robust automated fingerprint authentication systems coupled with the inherent ease of fingerprint acquisition, has led to its widespread commercial and civilian applications. One of the world's largest fingerprint recognition systems is the Integrated Automated Fingerprint Identification System (IAFIS), maintained by the FBI in the US since 1999.

Fingerprint recognition is the most popular way to identify a person, because of feasibility, permanence, distinctiveness, reliability, accuracy, and acceptability. A fingerprint is a pattern of ridges and valleys. The ridges are the dark areas of the fingerprint and the valleys are the white areas that exist between the ridges.

II. FINGERPRINT CLASSIFICATION

Fingerprint classification involving 6 classes with critical points in a fingerprint called core and delta marked as circles and triangles given in a figure 1 [1]. Many classifications are given to patterns that can arise in the ridges of a fingerprint (see Fig. 2). These points are called the minutiae of the fingerprint. The most commonly used minutiae in current fingerprint recognition technologies are ridge endings and bifurcations, because they can be easily detected by only looking at points that surround them (Bifurcation is the location where a ridge divides into two separate ridges). A good quality fingerprint contains 30 – 80 minutiae points.

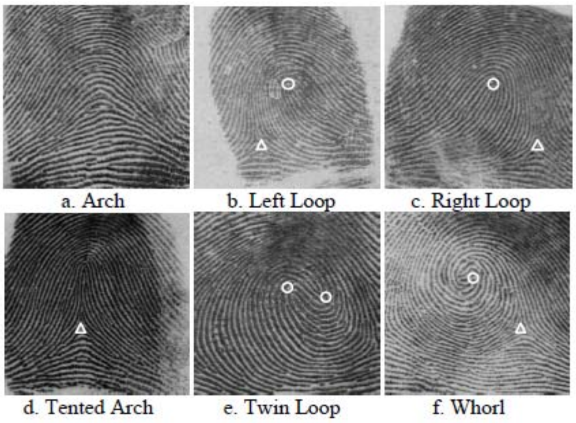


Fig. 1: Fingerprint classification.

A fingerprint is an impression of the epidermal ridges of a human fingertip. A hierarchy of three levels of features, namely, Level 1 (pattern), Level 2 (minutiae points) and Level 3 (pores and ridge shape) are used for recognition purposes (see Fig.2).

Level 1 features refer to the overall pattern shape of the unknown fingerprint—a whorl, loop or some other pattern. This level of detail cannot be used to individualize, but it can help narrow down the search.

Level 2 features refers to specific friction ridge paths — overall flow of the friction ridges and major ridge path deviations (ridge characteristics called minutiae) like ridge endings, lakes, islands, bifurcations, scars, incipient ridges, and flexion creases.

Level 3 detail refers to the intrinsic detail present in a developed fingerprint — pores, ridge units, edge detail, scars, etc. High resolution sensors (~1000dpi) are required for extraction of Level 3 features [2].

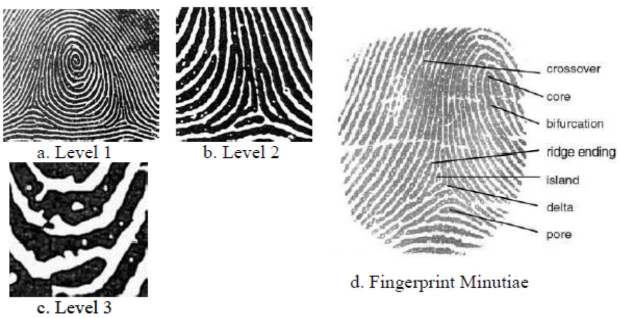


Fig. 2: Fingerprint Features

III. FEATURE EXTRACTION TECHNIQUES

For the purpose of automation, a suitable representation i.e. feature extraction of fingerprints is essential. This representation should have the following properties: a) Retention of discriminating power of each fingerprint at several levels of resolution; b) Easy computability; c) Amenable to automated matching algorithms; d) Stable and invariant to noise and distortions; e) Efficient and compact representation.

There are four categories of methods based on fingerprint feature extraction by image processing [3]. The first category of methods extract minutiae directly from the gray-level image [1] without using binarization and thinning processes while the second category extracts features from binary image profile patterns [4].

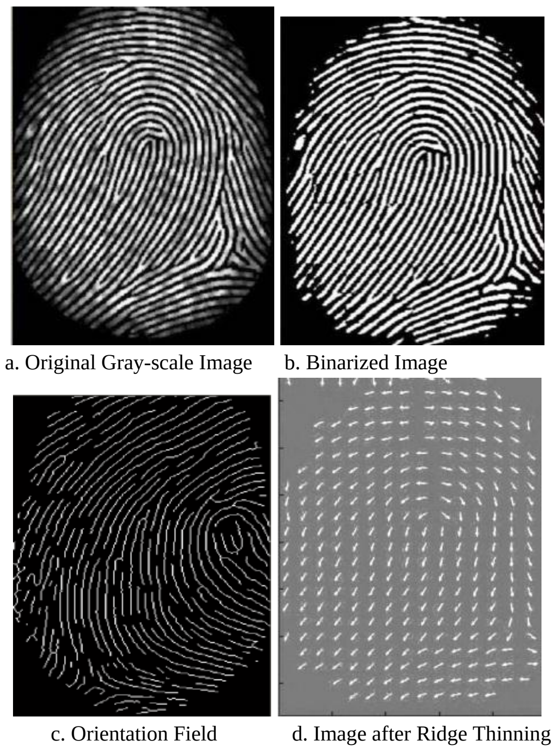


Fig. 3: Minutiae Extraction from Fingerprint Image

The third category of methods uses machine learning [5] for extracting minutiae and the

last category extracts minutiae from binary skeletons [6].

Binarization is the process by which an enhanced gray-level image is transformed into a binary image for subsequent feature detection. Good binarization algorithms should minimize information loss and also provide efficient computational complexity. A binarization approach based on the peak detection in the cross section gray-level profiles orthogonal to the local ridge orientation.

IV. MINUTIAE BASED FINGERPRINT RECOGNITION PROCESS

Minutiae based fingerprint recognition process includes the following steps: Binarization, Thinning (Block Filter), Minutiae Extraction, Minutiae Matching, Computing Matching Score (see Fig. 4) [2].

Binarization: In this step the fingerprint image is converted into grayscale, and then to binary data. In this step the image orientation is aligned, as it can have a different orientation from the template fingerprints, which are going to be used in the matching step.

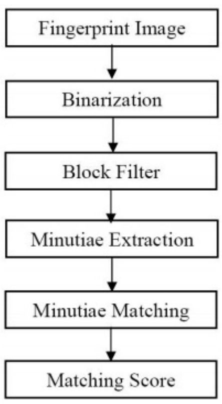


Fig. 4: Fingerprint recognition steps

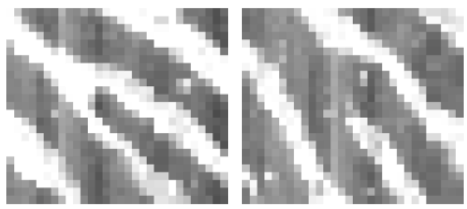
Block Filter: The binarized image is thinned to reduce the thickness of all ridges lines to one pixel width.

Fig. 5: Binarized and thinned fingerprint.

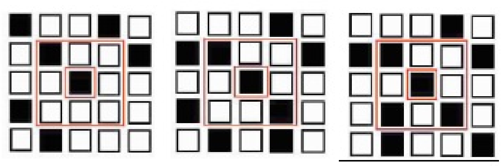
This step will help to extract minutiae points, as thinning does not change the location of the minutiae points compared to the original fingerprint.

Dilation and *erosion* are used to thin the edges. There are several algorithms for thinning edges and preserving the minutiae points (for example: Zhang-Suen algorithm, edge enhancement, etc.).

Minutiae extraction: This step derives the minutiae locations and angles. The terminations caused by the outer boundary are not considered as minutiae points. Crossing number (C_n) is used to identify the minutiae points. Crossing number is defined as half of the sum of differences between intensity values of two adjacent pixels. If crossing number is 1, 2, 3 or greater, then the minutiae points are considered as ending, normal ridge, bifurcation respectively (see Fig. 6).



(a) Ridge-ending (b) Bifurcation



(a) (b) (c)

Fig.6:

(a) Ending minutiae, C_n=1;
(b) Normal ridge pixel, C_n=2;
(c) Bifurcation minutiae, C_n=3.

Extracted minutiae points from the corresponding fingerprint are given in the figure below:

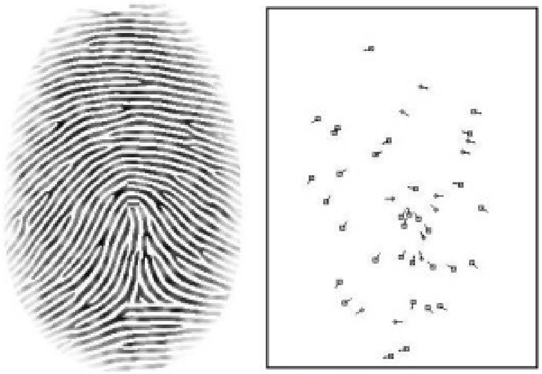


Fig. 7: Fingerprint and extracted minutiae points.

Minutiae Matching: In this step the fingerprint data is compared with the template data of the system. The extracted minutiae data is stored as a matrix with number of rows equal to number of minutiae points, and with four columns: column 1 is the row index of each minutiae point; column 2 is the column index of each minutiae point; column 3 is the orientation angle of each minutiae point; column 4 is the type of minutiae (1 – ending, 2 – bifurcation, 3-normal ridge).

During the matching process each minutiae point is compared with the template data. There are several algorithms for comparing minutiae. One of them converts template data points to polar coordinates using the following equation:

where for a template image:

r_k^T = radial distance of k^{th} minutiae,

φ_k^T = radial angle of k^{th} minutiae,

θ_k^T = orientation angle of k^{th} minutiae,

row_{ref}^T, col_{ref}^T = row and column index of reference points currently being considered.

The input data matrix points are converted to polar coordinates using the following equation:

rotatevalues – the difference between the orientation angles of T_k and I_m. T_k and I_m represent the extracted data in all the columns of row k and row m in the template and input matrices, respectively.

V. FINGERPRINT MATCHING TECHNIQUES

Matching fingerprint images is an extremely difficult problem, mainly due to the large variability in different impressions of the same finger. Fingerprint matching algorithms are roughly classified into 3 major categories.

Correlation-based Matching: Two fingerprint images are superimposed and the correlation between corresponding pixels is computed for different alignments (e.g. various displacements and rotations). Fourier transform can be used to speed up the correlation computation.

Feature-based (or Minutiae-based) Matching: Typical fingerprint recognition methods employ feature-based matching, where minutiae (i.e., ridge ending and ridge bifurcation) are extracted from the registered fingerprint image and the input fingerprint image, and the number of corresponding minutiae pairings between the two images is used to recognize a valid fingerprint image. Alternatively, Jain et al. [7] used a string matching technique while Isenor and Zaky [8] propose a graph-based fingerprint matching algorithm. In are [9] describes a fingerprint verification algorithm based on a bipartite graph construction between model and query fingerprint feature clusters.

The minutiae matching problem has been generally addressed as a point pattern matching problem which has been

extensively studied yielding families of approaches known as relaxation methods, algebraic and operational research solutions, tree-pruning approaches, energy-minimization methods, Hough transform, etc.

Pattern-based (or Image-based) Matching: Pattern based algorithms compare the basic fingerprint patterns (e.g., local orientation and frequency, ridge shape, texture information) between a previously stored template and a candidate fingerprint. The images need to be aligned in the same position, about a central point on each image. The candidate fingerprint image is then graphically compared with the template to determine the degree of match.

The image-based techniques include both optical as well as computer-based image correlation techniques. Recently, several transform-based techniques have also been explored. For instance, a phase-based fingerprint image matching technique using 2D discrete Fourier transforms has been proposed in [10] while in [11] describes a Gabor filter based fingerprint matching technique.

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CURRENT AND FUTURE WORK

The authors are working on the development of a software system based on the above described algorithm. The system will be used for testing the algorithm and optimizing the steps of the feature extraction and matching processes based on the test results.

REFERENCES

1. D. Maltoni, D. Maio, A. K. Jain, S. Prabhakar, Handbook of Fingerprint Recognition, Springe, 2003.

2. Q. Zhao, A. K. Jain, "On the Utility of Extended Fingerprint Features: a Study on Pores", IEEE Computer Society Workshop on Biometrics, CVPR2010, San Francisco, U.S., June 18, 2010.

3. R. C. Gonzalez and R. E. Woods., Digital Image Processing, Prentice Hall, Upper Saddle River, NJ, 2002.

4. R. S. Germain, A. Califano, and S. Colville, "Fingerprint matching using transformation parameter clustering", IEEE Computational Science and Engineering, pp. 42–49, Oct-Dec 1997.

5. S. Prabhakar, A. K. Jain, and S. Pankanti, "Learning fingerprint minutiae location and type", Pattern Recognition, 36(8):1847–1857, 2003.

6. F. Zhao, X. Tang, "Preprocessing and post- processing for skeleton-based fingerprint minutiae extraction", Pattern Recognition, Vol. 40, No 4, pp.1270–1281, 2007.

7. A. K. Jain, L. Hong, R. M. Bolle, "On-line fingerprint verification", IEEE Trans. on Pattern Analysis and Machine Intelligence, Vol. 19, No 4, pp.302–313, 1997.

8. D. K. Isenor, S. G. Zaky, "Fingerprint identification using graph matching", Pattern Recognition, Vol. 19, No 2, pp. 113–122, 1986.

9. K.-C. Fan, C.-W. Liu, Y.-K. Wang, "A fuzzy bipartite weighted graph matching approach to fingerprint verification", In Proc. of the IEEE International Conf. on Systems, Man and Cybernetics, pp. 729–733, Oct 1998.

10. K. Ito, T. Aoki, H. Nakajima, K. Kobayashi, T. Higuchi, "A fingerprint recognition algorithm using phase-based image matching for low-quality fingerprints", Proc. IEEE International Conference on Image Processing, 2005.

11. Y. Hamamoto, "A Gabor filter-based method for identification", Intelligent Biometric Techniques in Fingerprint and Face Recognition, pp. 137–151. CRC Press, Boca Raton, 1999.